Space Weather Technical Forecast

Issued on Monday, 11 December 2023 at 13:18 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of further isolated M-flares, mainly Days 1-2 (11-12 Dec).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate, with the peak flare M1.4 at 10/2243 UTC from AR3511 close to the southwest limb, which remains the most active region. In total there are currently eight sunspot regions on the disc, including newly numbered AR3517 close to centre disc in the northern hemisphere. AR3510 has faded from view in the past 24 hours. AR3513 at north centre disc continues to evolve slowly and has developed two small delta spots in its central portion. AR3514, to the south of AR3513, has redeveloped into a bipolar region in recent hours. The remaining regions are currently relatively small and simple at the present time, and have exhibited either minimal change or decay.

No Earth-directed CMEs were observed in available imagery. However, a filament disruption in the northwest disc was observed on SDO/AIA-0304 around 11/0800 UTC and a dimming event was observed 11/0900-1100 UTC close to centre disc, both of which may have produced a CME which is not yet discernible on LASCO imagery.

Solar Wind / Geomagnetic Activity: Solar winds as observed by ACE and DSCOVR at L1 were at slow-ambient levels. Wind speeds as measured by ACE were around 350km/s, but have gradually declined to 310-320 km/s. Density has remained below average throughout. The Total Interplanetary Magnetic Field (Bt) was weak, at or below 5nT, while the north-south component (Bz) varied weakly. Phi angle was predominately negative (towards the Sun). Geomagnetic activity was Quiet (Kp 0-1).

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at background levels. GOES16 high energy (greater than 2MeV) electron flux was predominantly moderate, peaking at 839pfu at 10/1720UTC. The 24-hour fluence was below the Active threshold (1e8 integrated pfu) on a slightly declining trend. The observation at 11/0000UTC was 4.03e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low activity is expected, with a decreasing likelihood of further isolated M-flares, predominantly from AR3511 in the southwest or AR3513 in the north-centre disc. AR3511 is expected to rotate across the western limb during Days 1-2 (11-12 Dec). Further regions are expected to rotate onto the disc through the period, but there is no strong signal for any significant returning regions.

Solar Wind / Geomagnetic Activity: There are no Earth-directed CMEs currently expected in the forecast period. An enhancement to slightly elevated levels wind speeds from either CH77/+ or CH80/+ is possible during Day 1 (11 Dec), although these are difficult to observe so confidence remains low. A return to slow-ambient levels is then probable through Days 2-3 (12-13 Dec). CH79/+, which is a new feature for this rotation, is expected to become geoeffective sometime on Day 4 (14 Dec), likely seeing an increase to slightly elevated and potentially elevated levels.

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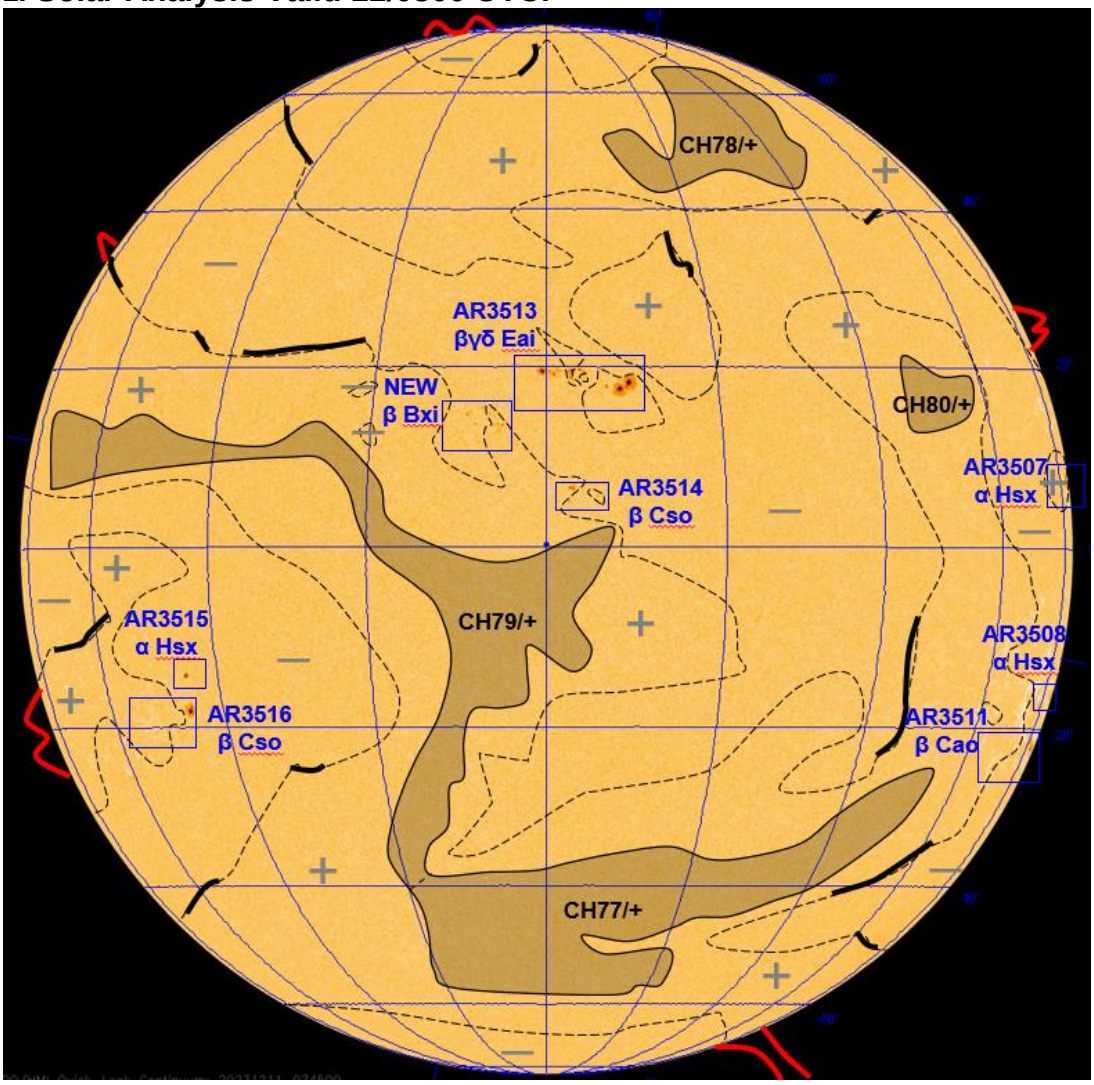
Current Quiet (Kp 0-2) geomagnetic activity may increase with the onset of any HSS from CH77/+ or CH80/+ to become Unsettled (Kp 3) with a slight chance of an Active interval (Kp 4) on Day 1. Activity is expected to then be largely Quiet, but with a similar increase in geomagnetic activity possible again on Day 4 with the onset of the HSS from CH79/+. Late Day 4 there is a very slight chance of an isolated G1/Minor Geomagnetic Storm interval (Kp 5), but this is considered a very low probability at this stage.

Energetic Particles / Solar Radiation: GOES16 high energy proton is expected to persist at background levels, with only a very slight chance of rising towards the S1/Minor Radiation Storm level given any significant flares from AR3511 or perhaps AR3513. This risk decreases as AR3511 rotates beyond the western limb. High energy electron flux is expected to be mainly moderate at first, perhaps declining from any HSS enhancements during Day 1 (11 Dec). Recovery to moderate levels then expected Days 2-3 (12-13 Dec) perhaps with diurnal peaks at high levels. A further drop out is possible with another HSS enhancement on Day 4 (14 Dec). The associated 24 hour fluence is expected to remain below the Active (1e8 integrated pfu) threshold.

Figure 1. Solar Analysis Valid 11/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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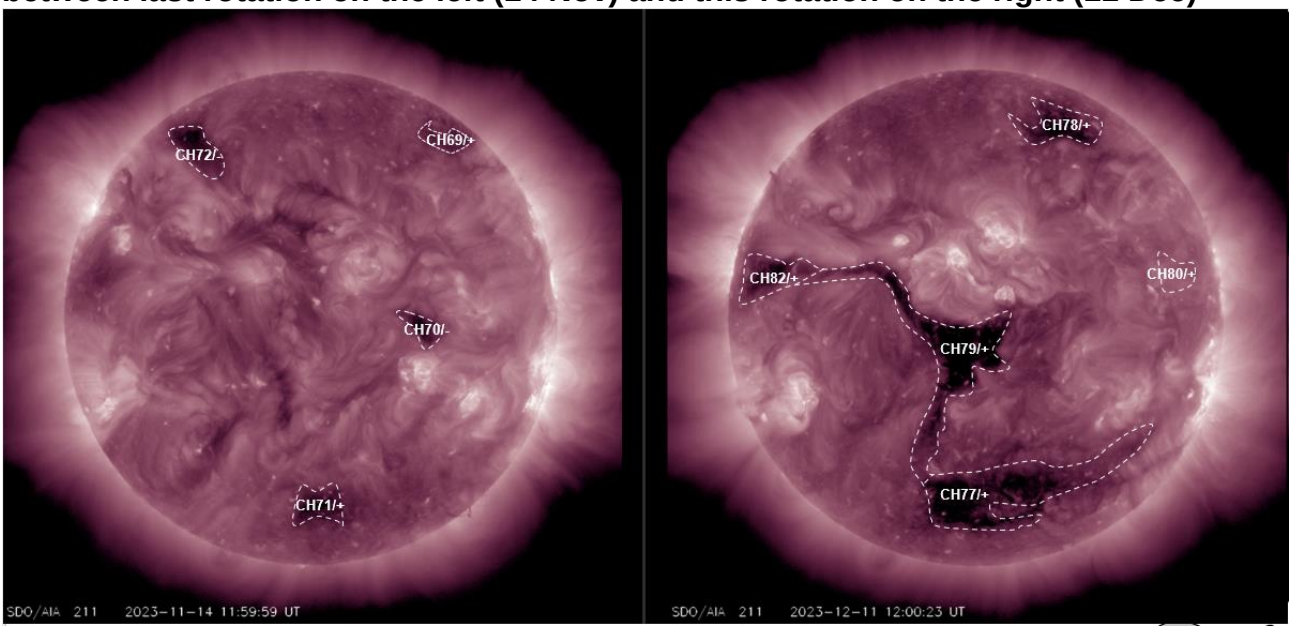
Figure 2. SDO/AIA-211 imagery comparing position and extent of coronal holes between last rotation on the left (14 Nov) and this rotation on the right (11 Dec)



Geomagnetic Storms:

There are no Earth-directed CMEs currently expected in the forecast period. However, a filament disruption in the northwest disc was observed on SDO/AIA-0304 around 11/0800 UTC and a dimming event was observed 11/0900-1100 UTC close to centre disc, both of which may have produced a CME which is not yet discernible on LASCO imagery.

A slight enhancement to solar winds is possible through Day 1 (11 Dec) due to contributions from the weakly discernible western portion of southern coronal hole CH77/+, or from the very small northwestern coronal hole CH80/+. This enhancement is indicated in Enlil modelling, however due to the obscured nature of the coronal holes confidence remains low. CH80/+ will likely pass quickly, while CH77/+ then becomes confined to more southerly latitudes, suggesting waning influence through Day 2 (12 Dec). CH79/+, which is a new feature for this rotation, is expected to become geoeffective sometime on Day 4 (14 Dec). Confidence is low in timing and peak wind speeds due to the non-persistent nature of this feature, but slightly elevated winds are expected, possibly reaching elevated levels.

Current Quiet (Kp 0-2) geomagnetic activity may increase with the onset of any High Speed Stream (HSS) from CH77 or CH80 to become Unsettled (Kp 3) with a slight chance of an Active interval (Kp 4) on Day 1. Activity is expected to then be largely Quiet, but with a similar increase in geomagnetic activity possible again on Day 4 with the onset of the HSS from CH79/+. Later Day 4 there is a slight chance that the onset of the HSS may produce an isolated G1/Minor Geomagnetic Storm interval (Kp 5), but this is considered a very low probability at this stage.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	**G1 to G2**	No	1	1	1	5
Strong	**G3**	No	1	1	1	1

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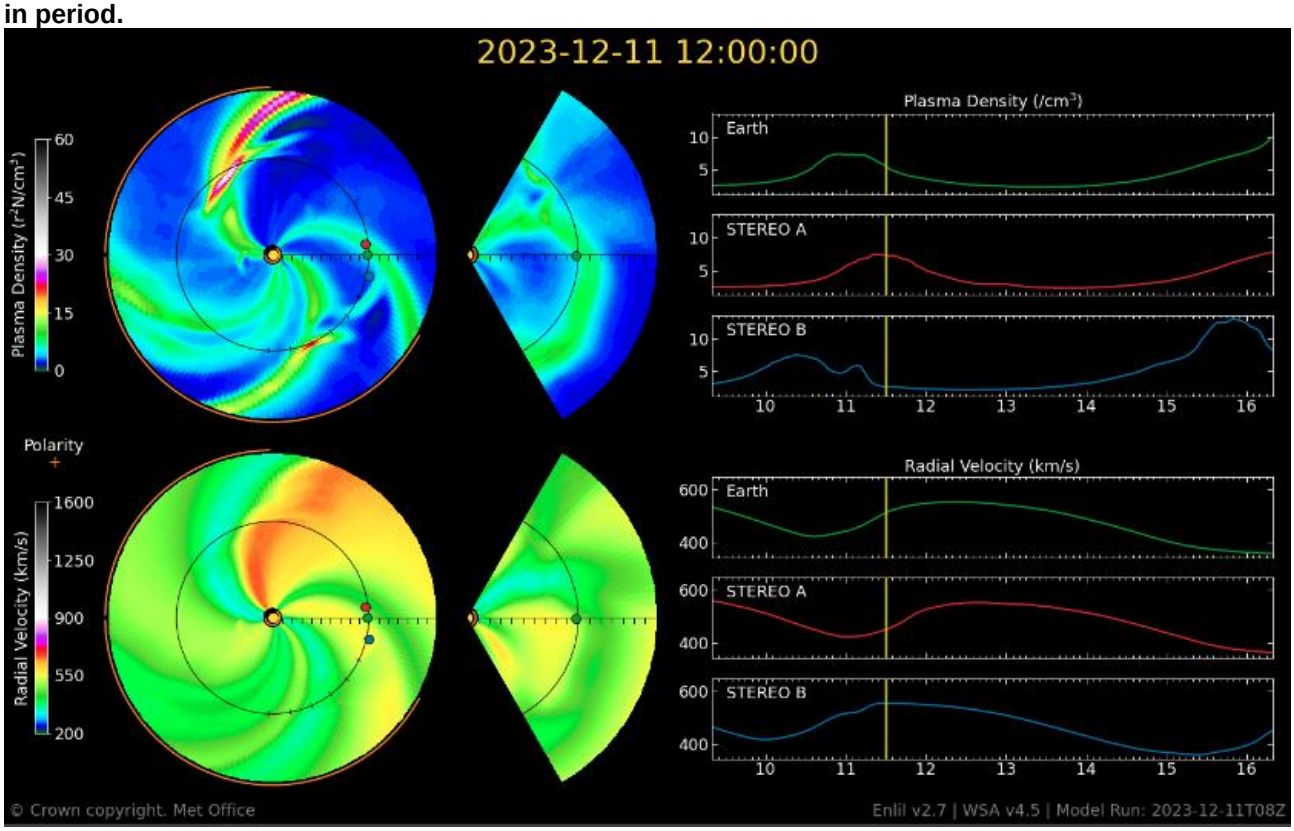
Severe	**G4**	No	1	1	1	1
Extreme	**G5**	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

No Earth-Directed CMEs currently expected.

Figure 3: MOSWOC Enlil, considered a good steer, although perhaps too slow with onset of HSS late in period.



Radio Blackouts - X-Ray Flares:

Low activity is expected through the period, with a decreasing likelihood of further isolated M-flares.

There are currently eight sunspot regions on the visible disc. The most active region remains AR3511 (Cao/Beta), which lies close to the southwest limb and is becoming increasingly difficult to view and analyse. However, the trailing portion appears to have decayed significantly leading to the recent reclassification of the group from Fao/Beta. This may not fully reflect the magnetic complexity of the group accurately, as the lead portion had been the more developmental element in recent days. AR3513 (Eai/Beta-Gamma-Delta) is the largest region on the disc and continues to evolve slowly, with the development of two small delta spots in its central portion. AR3514 has recently seen regions of opposite polarity form, leading to reclassification of the group as Cso/Beta. A new region to the south of AR3513 has been recently numbered AR3517. All other regions are currently relatively small and simple at the present time.

AR3511 will rotate off the disc early Day 2 (12 Dec), with the flare risk reducing as this rotates further away from the west limb. Seismic analysis of the far-side would suggest that new regions may rotate onto the east limb in the coming days, supported by areas of brightness visible beyond the east limb on SDO AIA-0094.

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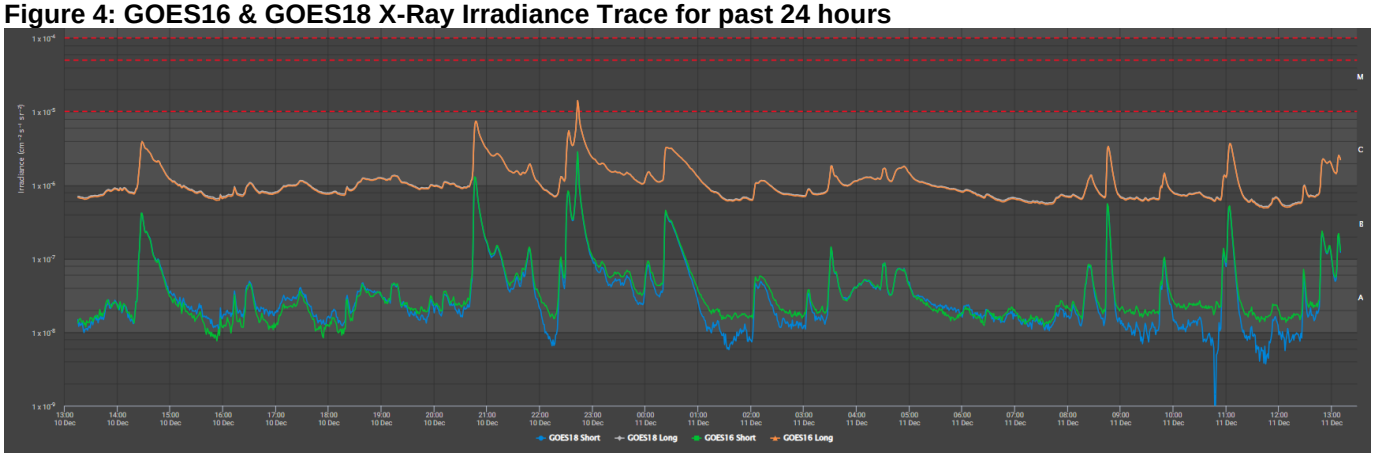
X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**R1-R2 M Class**	Yes	50	40	30	30
Very Active	**R3 to R5 X Class**	No	5	5	5	5

Figure 4: GOES16 & GOES18 X-Ray Irradiance Trace for past 24 hours



Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at background levels. There is a slight chance of this increasing should there be any significant flares on the disc, especially from AR3511 on the southwest limb, and also from AR3513 as it moves into the western hemisphere. The risk reduces somewhat by Day 3 (13 Dec) as AR3511 rotates away from the west limb after rotating off the disc early Day 2 (12 Dec).

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy electron flux, as observed by GOES-16, has been mainly moderate over the last few days, following waning solar wind enhancement from a recent coronal hole. This may drop towards background levels with any enhancement from either CH77/+ or CH80/+ on Day 1 (11 Dec). Some recovery in flux, to moderate levels, is then likely Days 2-3 (12-13 Dec), possibly reaching a diurnal peak at high levels. This is supported by the BAS-RBM relativistic electron

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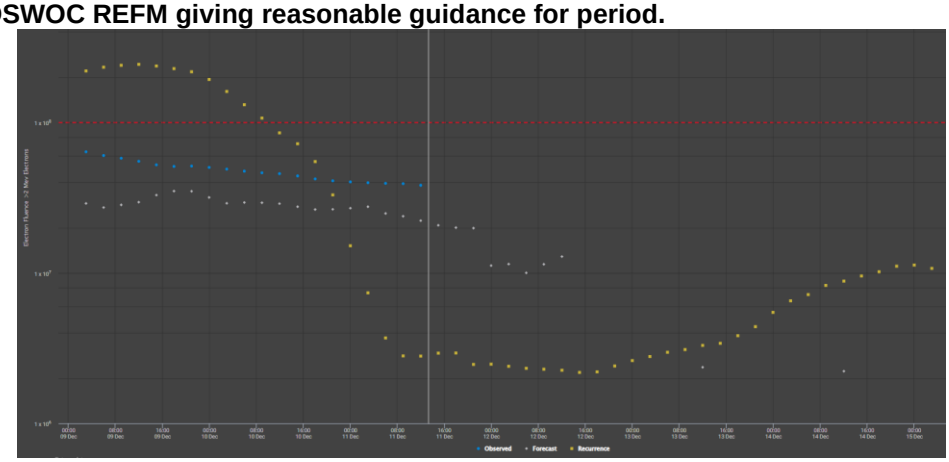
forecast which has provided a reliable steer in recent days. A suppression is then anticipated at some point from Day 4 (14 Dec) with the likely HSS enhancement from CH79/+.

The associated 24 hour fluence is expected to remain below the Active threshold through the period. A slight decline is probable on Day 1, before recovery on Days 2-3. It is unlikely this will reach the Active threshold, however, before a further decline is likely late Day 4 onwards. This is broadly supported by REFM, which keeps fluence below Active, although doesn't signal a notable rise on Days 2-3.

GEO Electron Environment Probability (Exceedance)	Level ($cm^{-2}\ sr^{-1}\ day^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	5	10	10
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 5: MOSWOC REFM giving reasonable guidance for period.



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